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# Test Vehicle Specifications

4

### GENERAL

ull-scale crash tests are the primary method for measuring the impact performance of a roadside safety feature. Proper selection, preparation, and instrumentation of the test vehicle are critical

F

components of the impact performance evaluation process. The test vehicles are chosen to be represen- tative of a wide range of vehicles. Procedures for preparation and instrumentation of test vehicles have been standardized as much as possible to improve consistency in the evaluation process. This chapter identifi es the recommended procedures for selecting, preparing, and instrumenting test vehicles.

For most devices, only two test vehicles are used to represent the entire fl eet of passenger cars operat- ing on the nation’s highways. These vehicles are selected based upon the philosophy that, if a safety feature performs satisfactorily for both the smallest and largest passenger vehicles, it should perform adequately for all vehicle sizes in between.

Surrogate test vehicles are sometimes used to evaluate the impact performance of breakaway systems and small traffi c control devices. Pendulum and bogie vehicle tests are used to evaluate the low-speed impact performance of breakaway signs and luminaire poles and high-speed bogie tests can be used to evaluate the impact performance of work-zone traffi c control devices. The mass and stiffness of these vehicles must be controlled to properly match existing test vehicles.

The following sections describe the fi ve production test vehicles and the surrogate test vehicles in greater detail, provide guidance for preparing the vehicles for use in the testing, and present tech- niques for instrumentation and data collection during the testing.

### TEST VEHICLE DESCRIPTIONS

The small test vehicle is selected to be representative of the 2nd percentile in terms of vehicle weight for all passenger type vehicles sold in 2002. This vehicle was found to be a small sedan weighing approxi- mately 2,420 lb (1,100 kg). A review of all gasoline-powered sedans in this weight category showed that the vehicles were similar in length, height, width, and wheelbase. Therefore, any small passenger car weighing near 2,420 lb (1,100 kg) is deemed to be acceptable as the small car test vehicle.

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The large test vehicle was selected to be representative of the 90th percentile in terms of vehicle weight for all passenger vehicles sold in 2002. As may be expected, all vehicles in this weight category are light trucks, including many four-door sport utility vehicles and a variety of pickup trucks. Large sport utility vehicles (SUVs) make up the highest proportion of vehicles with a mass of 5,000 lb (2,270 kg) or greater. Large SUVs typically have high centers of gravity (c. g.), ranging from a low of 28 in. (710 mm) to a high of 29.5 in. (750 mm) (62). In light of the lower costs for used pickup trucks compared

to large SUVs, a two-wheel-drive, four-door, half-ton pickup truck, weighing approximately 5,000 lb (2,270 kg), was selected to represent the large passenger vehicle class. These pickup trucks were found to have masses and center of gravity heights similar to those of large SUVs. In an effort to ensure that test vehicles have a center of gravity in the same range as large SUVs, a minimum c. g. height of 28 in. (710 mm) was selected for the pickup truck test vehicle.

A mid-size test vehicle has also been selected for use in evaluating the performance of staged en- ergy-absorbing systems. This alternate test vehicle, designated 1500A, will only be required when the

analytical procedures for evaluating crash cushion and terminal performance described in Appendix G indicate a potential failure. A sedan weighing 3,300 lb (1,500 kg) was selected as the most representa- tive vehicle body style and as the most appropriate mass to explore these occupant risk measures.

It should be noted that the passenger vehicle fl eet is changing constantly as a function of consumer preferences and other unforeseen circumstances, such as fuel availability and pricing. The selected test vehicles should be reviewed periodically to make sure that they remain representative of the current ve- hicle fl eet. Appendix H outlines a recommended procedure for re-evaluating and selecting test vehicles when changes in the vehicle fl eet are deemed signifi cant enough to revise the test vehicles.

The remaining three test vehicles are heavy trucks selected to provide strength and containment tests for median barriers and bridge railings. These vehicles include a single-unit van truck weighing 22,000 lb (10,000 kg), a tractor-van trailer weighing 80,000 lb (36,000 kg), and a tractor-tank trailer weighing 80,000 lb (36,000 kg). All heavy truck test vehicles should incorporate a cab-behind-engine confi gura- tion, not a cab-over-engine design. The single unit truck was selected to provide a reasonable increment in barrier capacity between the new passenger vehicle strength test and the tractor-trailer strength tests. The masses of the two tractor-trailer tests were selected to be representative of the most common tractor- trailer weight combinations. The van trailer test vehicle should have a semi-monocoque structural design and should include a sliding undercarriage (slide axles). The trailer rear tandems and axles should not be modifi ed in any way for the test. The tank-trailer test vehicle was selected to provide a maximum con- tainment test for median barriers and bridge railings that would prevent most tractor-trailer combinations from penetrating or rolling over the top of the barrier. In order to fulfi ll this objective, tank-trailers should have a minimum height to the center of the tank of 80.5 in. (2050 mm).

Surrogate test vehicles, including pendulum and bogie vehicles, are used to evaluate the behavior of breakaway devices during low-speed impacts and the behavior of work-zone traffi c control devices. Vehicle mass and the characteristics of the crushable nose of surrogate vehicles are the most critical parameters associated with these tests.

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4.2.1 PRODUCTION VEHICLES

All vehicles used in full-scale crash testing should be in good working condition with no signifi cant body damage or missing structural components such as windshield, bumper, or fenders. Special purpose vehicles, such as sports cars, should not be utilized because the suspension systems, c. g. heights, and weight distributions for these vehicles are outside the normal ranges of typical passen- ger cars. Bumpers on passenger vehicles should be standard equipment and unmodifi ed for the test. Similarly, original equipment bumpers should be used on heavy truck test vehicles whenever possible. Heavy, stiff, after market bumper systems should not be used.

Tires used in testing should match the manufacturer’s recommendations found on the vehicle certifi - cation plate. However, when necessary to meet recommended c. g. height requirements, vehicle tires may be changed to one of the factory-installed optional tire sizes available at the time of vehicle man- ufacture. All-season highway tires should be used on test vehicles, not mud or snow tires. Vehicles with aftermarket modifi cations to the vehicle body, suspension, or wheels should be restored to original manufacturer’s specifi cations prior to testing. Factory-installed optional equipment, such as power brakes and steering, anti-lock and anti-skid braking systems, and specialty wheels, are accept- able, provided the vehicle meets the overall guidelines presented below. In addition, fuel tanks should be purged and the battery removed to reduce exposure to needless hazards. However, with the new requirement to have the power on for test vehicles in order to collect Event Data Recorder (EDR) and airbag deployment data, a supplemental battery that is sealed and non-volatile will have to be used.

All passenger vehicles used in crash testing should be no more than 6 model years old on the day the test is conducted. It is recognized that some research projects can experience extensive delays. To eliminate the potential for these delays to require replacement of test vehicles purchased in anticipa- tion of testing, it is acceptable to utilize test vehicles that are within 6 model years of the date when the original research project was initiated. Although it is cost-prohibitive to apply the 6-year limit to heavy truck test vehicles, it is desirable to utilize vehicles of recent vintage. Heavy truck test vehicles should be representative of widely used designs.

Test vehicles are specified by basic body style and vehicle mass properties. All test vehicles should fall into the recommended ranges on basic vehicle mass properties. For the 2270P vehicle, a minimum vehicle c. g. height is also specified. Although it is recommended that vehicle c. g. height be measured after test preparation has been completed, measurement of a base vehicle is acceptable, provided the measured height is properly adjusted for mass changes associated with test preparation. Vehicle c. g. height should be measured using a suspension method, such as that described in Volume 4 of the *1986 SAE Handbook* (123). Alternate methods for measuring vehicle c. g. height may be employed, provid- ed the testing agency verifi es that the accuracy and precision of the alternate procedure is comparable to the suspension method.

In addition to the body style and mass parameters that must be met, ranges for other vehicle proper- ties, such as wheelbase, track width, and overall length, are presented to serve as a guide for test vehicle selection. When practical, test vehicles should be selected to conform to all the parameters shown in Tables 4-1 and 4-2. Also, when possible, passenger vehicles used in crash testing should be selected from one of the top three best-selling vehicle models within each test vehicle classifi ca-

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tion. Automobile sales data may be obtained from the *Automotive Yearbook* (147), published by Wards Reports, Inc., or the *Market Data Book* (37), published by the *Automotive News* magazine.

The 2270P test vehicle should be a half-ton, 2-wheel-drive, pickup truck with four full-size doors.

Note that even though some extended-cab pickups have four doors, including two small rear doors that cannot be opened independent of the front door, these vehicles do not conform to the 2270P vehicle rec- ommendations. The test vehicle should not have a special bed, such as a “Sportside” or “Stepside.” The 2270P vehicle may include a heavy-duty suspension supplied by the manufacturer, provided the vehicle mass properties and c. g. heights fall in the proper range.

The 2270P test vehicle must have a minimum c. g. height, in the ballasted confi guration, of 28 in.

(710 mm). This requirement will necessitate that the c. g. height for all 2270P test vehicles be measured and reported. Note that the vehicle c. g. height of a light truck can often be raised by as much as 1/2 in. (13 mm) by replacing worn tires, after-market tires, or both with tires meeting the size recommendation on the vehicle certifi cation plate.

Note that there is little consistency in the mounting of truck boxes to single-unit truck frames. Weak attachments can allow the cargo box to separate from the truck frame, thereby greatly reducing bar- rier loading during a full-scale crash test. To assure that the truck box attachment meets the minimum capacity requirement, testing agencies should evaluate the existing attachments relative to the attach- ment guidelines contained in Ford’s *2005 Body Builder Layout Book* (54). If the existing attachments

are found to be inadequate relative to the referenced guidelines, truck box attachments should be added, suffi ciently reinforced, or both to meet the guidelines.

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TABLE 4-1. Recommended Properties of 1100C, 1500A, and 2270P Test Vehicles

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|  |  |  |  |
| --- | --- | --- | --- |
| **Property** | **1100C**  **(Small Car)** | **1500A**  **(Intermediate Car)** | **2270P**  **(Pickup Truck)** |
| **MASS, lb (kg)** | 2420 ± 55 (1100 ± 25) | 3300 ± 75 (1500 ± 35) | 5000 ± 110 (2270 ± 50) |
| Test Inertial |
| Dummy | 165 (75) | Optionald | Optionald |
| Max. Ballast | 175 (80) | 440 (200) | 440 (200) |
| Gross Static | 2585 ± 55 (1175 ± 25) | 3300 ± 75 (1500 ± 35)d | 5000 ± 110 (2270 ± 50)d |
| **DIMENSIONS, in. (mm)** | 98 ± 5 (2500 ± 125) | N/A | 148 ± 12 (3760 ± 300) |
| Wheelbase |
| Front Overhang | 35 ± 4 (900 ± 100) | N/A | 39 ± 3 (1000 ± 75) |
| Overall Length | 169± 8 (4300 ± 200) | N/A | 237 ± 13 (6020 ± 325) |
| Overall Width | 65 ± 3 (1650 ± 75) | N/A | 78 ± 2 (1950 ± 50) |
| Hood Height | 24 ± 4 (600 ± 100) | N/A | 43 ± 4 (1100 ± 75) |
| Track Widtha | 56 ± 2 (1425 ± 50) | N/A | 67 ± 1.5 (1700 ± 38) |
| **CENTER OF MASS** | 39 ± 4 (990 ± 100) | N/A | 63 ± 4 (1575 ± 100) |
| **LOCATION,b in. (mm)** |
| Aft of Front Axle |
| Above Ground (minimum)c | N/A | N/A | 28.0 (710) |
| **LOCATION OF ENGINE** | Front | Front | Front |
| **LOCATION OF DRIVE AXLE** | Front | Front or Rear | Rear |
| **TYPE OF TRANSMISSION** | Manual or Automatic | Manual or Automatic | Manual or Automatic |

a Average of front and rear axles. b For “test inertial” mass.

c 2270P vehicle must meet minimum c. g. height requirement.

d. If a dummy (surrogate occupant) is used, the gross static vehicle mass should be increased by the mass of the dummy.

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TABLE 4-2. Recommended Properties of 10000S, 36000V, and 36000T Test Vehicles

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Property** | **10000S**  **(Single-Unit Van Truck)** | **36000V (Tractor/Van Trailer)** | | | **36000T (Tractor/Tank Trailer)** | | |
| **Tractora** | **Trailerb** | **Combination** | **Tractora** | **Trailerc** | **Combination** |
| **Mass, lb (kg)** | | | | | | | |
| Curb | 13,200 ± 2,200  (6000 ± 1000) | N/S | N/S | 29,000 ± 3,100  (13,200 ± 1,400) | N/S | N/S | 29,000 ± 3,100  (13,200 ± 1,400) |
| Ballastd | As Needed | N/A | As Needed | N/A | N/A | As Needed | N/A |
| Test Inertial | 22,046 ± 660  (10,000 ± 300) | N/S | N/S | 79,300 ± 1100  (36,000 ± 500) | N/S | N/S | 79,300 ± 1100  (36,000 ± 500) |
| **Dimensions, in. (mm)** | | | | | | | |
| Wheelbase (max) | 240 (6,100) | 200  (5100) | N/S | N/A | 200  (5,100) | N/S | N/A |
| Overall Length (max) | 394 (10,000) | N/S | 636 (16,155) | 780 (19,850) | N/S | N/S | 780 (19,850) |
| Trailer Over- hange (max) | N/A | N/A | 87 (2,200)f | N/A | N/A | 73 (1,850) | N/A |
| Cargo Bed Height g | 49 ± 2  (1,245 ± 50) | N/A | 50 ± 2  (1,270 ± 50) | N/A | N/A | N/A | N/A |
| **Center of Mass Location, in. (mm)** | | | | | | | |
| Ballast d (above ground) | 63 ± 2  (1,600 ± 50) | N/A | 73 ± 2  (1,850 ± 50) | N/A | N/A | 81 ± 4  (2,050 ± 100) | N/S |

1. Tractor should be a cab-behind-engine model, not a cab-over-engine model.
2. It is preferable that the trailer structure be of the “semi-monocoque” type construction. It is preferable that a sliding undercarriage (slide axles) be used to attach the trailer tandems to the trailer frame.
3. It is preferable that a gasoline tank trailer with an elliptical cross section be used. d See Section 4.2.1.2 for recommended ballasting procedures.
4. Distance from rearmost part of trailer to center of trailer tandems.
5. If trailer is equipped with slide axles, they should be set at rearmost position. g Without Ballast.

N/A – Not Applicable N/S – Not Specifi ed

###### Test Vehicle Mass

Vehicle mass properties are the most important factors affecting the performance of most highway safety features. Although total vehicle mass, sprung mass, unsprung mass, ballast mass, and rotational moments of inertia can affect the impact performance of safety features, experience has shown that reasonable consistency can be obtained by controlling the vehicle body style and vehicle curb mass, test inertial mass, gross static mass, and dummy mass as defi ned below.

**Curb mass**—mass of test vehicle in its standard manufacturer conditions with all fl uid reservoirs fi lled and without occupants or cargo. In general, curb mass should not vary signifi cantly.

**Test inertial mass**—mass of test vehicle including all items rigidly attached to the test vehicle, including secured ballast and test equipment. Test inertial mass does not include any loose ballast or surrogate occupants.

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**Gross static mass**—total mass of the test vehicle, including all surrogate occupants, ballast, whether it is secured or not, and all test equipment.

**Dummy mass**—mass of surrogate occupant.

Passenger vehicles should be selected to require the minimum amount of adjustment to the curb mass to achieve test inertial mass. Whenever possible, only seats, spare tires, fuel tanks, fl uids, and optional equipment should be removed from the vehicle in order to bring the vehicle into the proper mass range. Note that bench seat frames have been shown to contribute to the rigidity of some light truck vehicles and, as a result, the frames of these seats should not be removed from the 2270P test vehicles.

###### Ballast

Whenever test vehicles are found to have insuffi cient curb mass, fi xed ballast may be added to 1100C, 1500A, and 2270P test vehicles, up to the maximum amount shown in Table 4-1. Ballast installed

in passenger vehicles can be either concrete or metal blocks placed in the passenger compartment and rigidly attached to the vehicle structure by metal straps or other devices capable of withstand- ing a static load of 20 times the ballast weight in both the longitudinal and lateral directions. Ballast

should be distributed to minimize changes to the horizontal and vertical locations of the vehicle center of gravity in its curb mass condition. If necessary to minimize movement of the vehicle c. g., some ballast may be placed in the bed of the 2270P vehicle. It is important to note that the vertical c. g. location of the 2270P vehicle should be 28 in. (710 mm) or greater after all ballast is added to the vehicle. In general, ballast should not be used to raise the c. g. height of test vehicles that otherwise would not conform to the minimum height requirements.

Heavy truck test vehicles, 10000S and 36000V, must be ballasted with simulated cargo to reach the target gross static mass values shown in Table 4-2. Ballast used in these vehicles can include sand- bags, concrete or steel blocks, bales of hay, or other means. Ballast should be as uniformly distributed across the length and width of the cargo bed as possible. When heavy materials such as steel, con- crete, or sand are used as ballast, they should be placed on top of a platform to raise the ballast c. g. to the proper height. Wooden pallets can be used to create the platform, but any means that provides

the proper total cargo c. g. height is acceptable. Ballast should be fi rmly secured to prevent movement during and after the test.

Water should be added to the tank trailer on the 36000T test vehicle to achieve the nominal test inertial mass shown in Table 4-2. If the tank trailer has compartments, the water should be distributed among the compartments to provide a ballast c. g. location that is as close as possible in both the longitudinal and vertical directions to the c. g. location achieved when all tanks are fi lled. Further, it is desirable to fi ll as many compartments as possible in order to minimize sloshing effects during the crash test.

Any ballast used in a test vehicle should be thoroughly documented. At a minimum, this documenta- tion should include the ballast type, mass, location, center of mass, attachment method, and, when appropriate, photographs of the ballast.

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###### Propulsion, Guidance, and Braking

The test vehicle may be propelled into the test article in any reliable fashion, including towing, push- ing, or self-propelled. The vehicle should be disengaged from the towing or pushing mechanism and be “free wheeling” during and after impact. When the test vehicle is self-propelled and remotely controlled, the engine should be turned off just before impact. Using live drivers to accelerate and steer test vehicles should generally be avoided. If implemented, special precautions should be taken to protect the driver from high vehicle accelerations and minimize the risk of vehicle rollover.

Any reliable method for guiding test vehicles into the test article is acceptable, provided the guidance system can be removed from the test vehicle prior to impact and any components remaining attached to the vehicle do not infl uence the outcome of the test. Many agencies utilize a cable guidance system attached to one of the front tires. Although this system has proven to be reliable, a small hub normally remains attached to one of the front tires during the crash test. In the past, some of these hub com- ponents have contacted the ground during violent vehicle motions and stabilized some vehicles that appeared to be on the verge of rolling over and tripped some vehicles that otherwise seemed likely to remain upright. Special care should be taken to place this hub or any similar guidance system com- ponent that remains attached to the vehicle in a location that will not allow the element to contact the test article or the ground.

Application of test vehicle brakes should be delayed as long as possible in order to establish the post-impact vehicle attitude and trajectory. It is especially important to delay brake application until vehicle stability is clearly established. Further, brakes should not be applied until 2 seconds after the

vehicle has completely lost contact with the test article. The position of the test vehicle at the point of brake application should be reported.

###### Vehicle Damage

The extent of vehicle damage that occurs during the test should be documented photographically and through damage scales and direct measurements. Pre- and post-test photographs should be taken to document all interior and exterior test vehicle damage, including underside of occupant compartment and undercarriage components (e.g., floorboard, rear trunk, fuel tank, and oil pan). Vehicle damage should be documented using the Vehicle Damage Scale (VDS) (89), Collision Damage Classifi cation (CDC) (122), and National Accident Sampling System, Vehicle Measuring Techniques (88).

It is also necessary to measure occupant compartment deformation during the test by accurately mea- suring vehicle interior dimensions prior to and after the test. A procedure for measuring the occupant compartment interior has been developed and is described in detail in Appendix E. This procedure incorporates a three-dimensional coordinate system that is established using points on the vehicle interior that are not expected to deform during the test. The coordinate system is used to identify the position of the interior surface with respect to the vehicle reference points, both before and after the full-scale crash test. The pre- and post-test positions can then be compared to measure the extent of vehicle deformation. Pre- and post-impact configurations of the vehicle’s interior should also be well documented photographically.

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###### Surrogate Occupants

Although occupant risk during full-scale crash testing is to be determined by application of the “flail space” model, a surrogate occupant is recommended to be used during tests involving the 1100C vehicle. The surrogate occupant is specified to evaluate unsymmetrical vehicle mass distribution and its effect on vehicle stability. When utilized without instrumentation, a surrogate occupant should be a Hybrid I or II dummy, representative of a 50th percentile male with a mass of approximately 165 lb (75 kg), and should be placed into either the driver or right front passenger seat. For most 1100C tests, the location of the dummy should be selected to maximize vehicle roll, pitch, and yaw motions during the testing. The dummy should be secured in the seat with a seat belt, including both lap belt and shoulder harness.

A 50th percentile male dummy should also be used when there is a potential for an occupant to extend out of the vehicle and come into direct contact with the test article. This situation primarily arises with tall barrier systems without suffi cient set-back at the top of the barrier or with luminaire and sign sup- ports placed on top of barrier systems. In this case, the head of an occupant placed in the front seat on the impact side of the vehicle can extend out of the vehicle window and contact the top of the barrier or the support structure. It is recommended that dummies be placed in the front seat on the impact side of both 2270P and 1100C vehicles during testing of any longitudinal barrier with a height greater than or equal to 33 in. (840 mm) or if luminaire and sign supports are placed on top of the barrier. For this application, the dummy should be restrained with a lap belt and shoulder harness. An onboard camera or tightly zoomed external cameras placed parallel with the barrier should be used to docu- ment the dummy’s head movement during the test.

Although not required for impact performance evaluation of common safety features subjected to conventional impact conditions, instrumented dummies are recommended for use in roadside safety research efforts, particularly when there is potential for occupant compartment deformation or intru- sion. Side impact testing is one area where extensive vehicle deformation is expected and further research into the refi nement and application of impact performance evaluation guidelines is needed. Researchers are encouraged to utilize the instrumented dummy most appropriate for each type of test- ing. Side impact dummies are likely to be most appropriate for side impact testing while Hybrid III or THOR dummies may be more appropriate for oblique impact testing.

###### Documentation

The pre-test conditions of all test vehicles should be well documented. Figures 4-1 through 4-5 present vehicle data items that should be measured and recorded for any full-scale crash test. It is preferable that these data elements be presented in the format shown in these figures in order to pro- mote consistency among test agency reporting. Any dimensions that fall outside of the recommended tolerances should be noted in the test report, along with a brief assessment of what affect the deviation may have had on the crash test. Note that frame height measurements on the 2270P vehicle should be taken at the ends of the frame rail and measured to the bottom of the rail element. In addition, the longitudinal location of the center of mass of trucks, tractors, and trailers should be reported. Pre-test photographs of the test vehicle should be taken to sufficiently document both the exterior and the interior conditions of all test vehicles. For passenger vehicles, in addition to the areas described in Section 4.2.1.4, pre-test photographs should include the interior floorboard and the rear trunk interior. The pre-test interior photographs should be taken with carpet, padding, and passenger seats removed. However, passenger seats would be reinstalled for the actual crash test and later removed for detailed post-test documentation and photography.

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Da te :

Te s t N u m b e r:

Mo d e l:

Ma k e :

Ve h ic le I.D.# :

Tire S iz e :

Y ear: O dom e ter:

T ire In fla tio n P re s s u re :

\*(A ll M e as urem en ts R efer to Im pa c tin g S id e )

V e hic le G e om etry – in. (m m )

a b

cL

a m veh icle n t

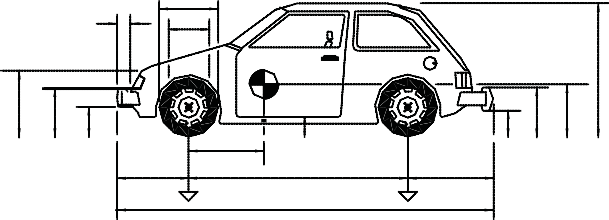
c d e f

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r m n

o

j

i s

f h e

W fro n t c

b

l g

k

d

Wre a r

o p q r s t

W h ee l C e nter H e ig h t

M as s D is tribu tion

LF R F LR R R

Engine Type Engine Size T ra n sm is sio n T y p e :

A utom atic o r M anual

F W D o r R W D or 4W D

We ig h ts lb (k g )

C urb (N o F u el)

T e s t In e rtia l G ro s s S ta tic

W front W re a r W to ta l

Du m m y Da ta

Ty p e : Ma s s :

GVWR Ratings

Front Rear

Total

Se a t P o s itio n :

N ote an y da m a ge p rior to tes t:

Figure 4-1. 1100C and 1500A Vehicle Parameters

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Da te :

T e st N u m ber:

Mo d e l:

Ma k e :

V e hicle I.D .#:

Tire S iz e :

Y ear: O dom e ter:

\*(A ll M e a s u re m e n ts R e fe r to Im p a c tin g S id e )

V e hic le G e om etry – m m (in .)

a b

a m n t

c d e f g h

Tire Diameter q

Test Inertial C.M.

i j k l

Wheel Diameter

p

o

j i

f

r

h Wfront

b g

s k l

e d

Wrear c

m n o p q r s t W hee l C enter H eig ht Front

W h ee l C e nter H eig h t R e a r Wh e e l We ll C le a ra n c e (F )

Ma s s

D istribution

LF

LR

RF RR

Wh e e l We ll C le a ra n c e (R ) Fram e H e ig h t (F ) Fram e H e ig h t (R )

E ngine Ty pe

We ig h ts lb (k g )

W front W re a r W to ta l

C u rb T es t In ertial G ros s S tatic

E ngine S iz e

T ra n sm is sio n T y pe:

A u to m a tic or M a nual F W D o r RW D o r 4 W D

GV W R Ra tin g s

Fro n t Ba c k To ta l

Du m m y Da ta

T y pe: M a ss:

Se a t P o s itio n :

N o te a n y d a m a g e p rio r to te s t:

Figure 4-2. 2270P Vehicle Parameters

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Da te : Te s t N u m b e r: Model: Tire Sz FR : O d om eter: Make: Tire Sz R R : V .I.N . # : Ye a r:

t c

n u w v

p z

x

m aa

a

q

b y

r

o g

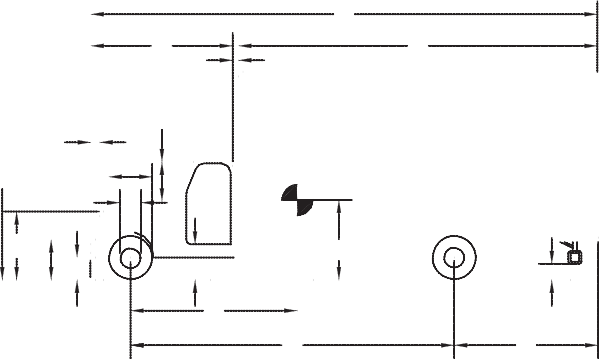
l

j i s k

h

f e d

V ehic le G eom etry – in . (m m )



a) fr. bum p. w id th

j) fr. bum p . to p s)

bot. door h e ig h t

b) ov erall h e ig h t k) rr. b u m p . b o t.

t) ov erall w id th

c) ov erall le n g th

1. rr. fra m e to p u)

ca b le ngth

* 1. rear ov e rh a n g m) fr. tra c k w id th
  2. w heel b a se n) ro o f w id th
  3. front ov e rh a n g o) hood he ig h t
  4. c. g. h e ig h t p) bum p. ex te n sio n
  5. c. g. h o r. d ist. q) fr. tire w id th

1. traile r/b o x le n g th
2. gap w id th
3. ov erall fr. h e ig h t
4. ro o f-h o o d d ist.
5. roof height d if.
   1. fr. bum p. b o t. r) fr. w heel w id th

aa ) rr. tra c k w id th

W eights – lb (kg )

Wfro n t a x e l Wre a r ax el WTO T A L

C u rb T es t Inertia l G ros s S ta tic

w heel ce n te r

h e ig h t front

w heel ce n te r

height re a r

w heel w e ll

c learance (F R )

w heel w e ll

c learance (R R )

En g in e T y p e E ngine S ize

Ba lla st M a ss D istributio n

T ra n sm is sion T ype:

A u to m a tic or M anual F W D o r R W D o r 4 W D

LF

LR

RF

RR

N ote any dam age prio r to te st:

Figure 4-3. 10000S Vehicle Parameters

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Da te :

Te s t N u m b e r:

Tra c to r:

VIN N o .: M a k e : Y e ar: O dom ete r:

Tra ile r:

VIN N o .: M a k e : Ye a r:

Mo d e l:

Mo d e l:

P R A

Q

A/2

S Fifth Wheel

Ballast C.M.

T

U

W N

J

L

H

M O V

G

B C D E F K

M1 M 2 M 3

M 4 M 5

V ehic le G eom etry – in . (m m )

A G B H C J D K E L F M

N T O U P V Q W R

S

Mas s – lb (k g )

M1 M 2

M 3

M 4

M 5

M T

C u rb T e st In ertial G ro s s S tatic

N ote any dam age p rio r to te s t:

Figure 4-4. 36000V Vehicle Parameters

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Da te :

T es t N u m ber:

Tra c to r:

V IN N o .: M a k e : Ye a r: O d o m e te r:

Tra ile r:

V IN No .: Ma k e : Ye a r:

Mo d e l:

Mo d e l:

P R A

Q

A/2

S Fifth Wheel Ballast C.M.

T

U W

N

J

L

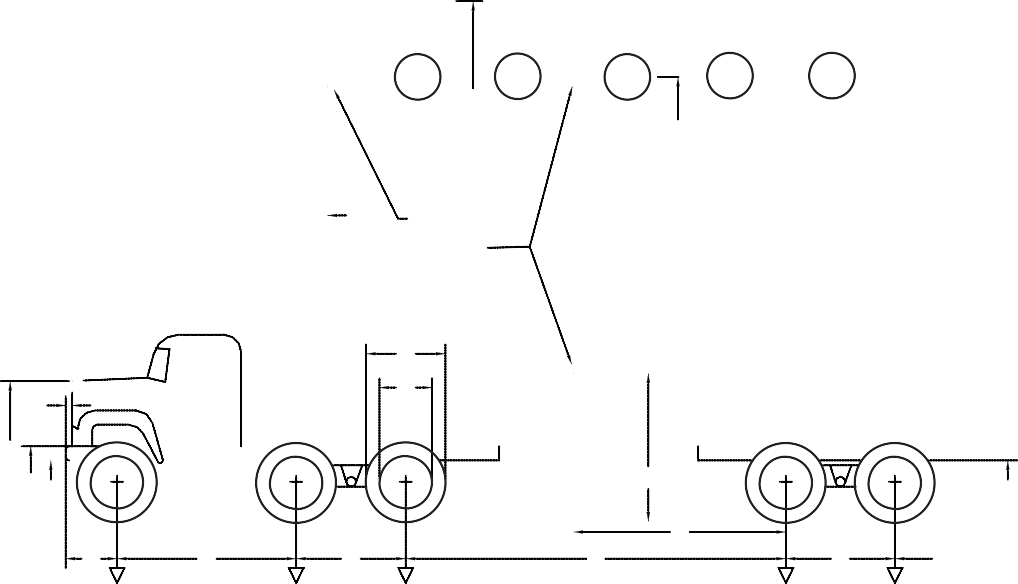
H

M O V

G

B C D E F K

M1 M2 M3



M4 M5

V e hic le G e om etry – in. (m m )

A G B H C J D K E L F M

N T O U P V Q W R

S

M a ss – lb (k g )

M1 M2 M3 M4 M5 MT

C u rb T e s t In e r tia l G ro s s S ta tic

N o te a n y d a m a g e p rio r to te s t:

Figure 4-5. 36000T Vehicle Parameters

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Vehicular impact speed and angle, impact point on the vehicle and the test article, exit speed and an- gle, vehicular accelerations, and the three-dimensional motion of the vehicle should be measured and reported. Exit speed and angle are measured at the time the vehicle loses contact with the test article. For some support structures such as a yielding sign support, the test article, or parts thereof, may stay with the vehicle for a considerable distance beyond impact. In these situations, the exit conditions can be measured when the vehicle clears the foundation or the footing of the test article. Note however that the point at which vehicle exit conditions are reported must be clearly defi ned. It is also recom- mended that vehicle deformation, both in the interior and on the exterior, be measured and recorded. Procedures for measuring vehicle deformations are presented in Appendix E. Other vehicle param- eters that should be measured and recorded include contact length with the barrier, airborne distance of the vehicle, and maximum rise of the vehicle’s bumper and wheels.

* + 1. SURROGATE TEST VEHICLES

Surrogate test vehicles, including pendulums and bogie vehicles, may be used to evaluate the im- pact performance of breakaway systems and work-zone traffi c control devices. For these tests to be an acceptable replacement of crash testing with production vehicles, (1) the surrogate vehicle must possess the same essential properties as the production vehicle it is intended to replicate; and (2) the production vehicle model that is replicated must meet the vehicle recommendations of Section 4.2.1. It should be noted that, at the time of this writing, mass and crushable nose properties for all available surrogate vehicles are out-of-date and do not replicate any vehicle included in Section 4.2.1. Hinch et al. (60) presents methods for identifying essential properties for surrogate vehicles to be used in the evaluation of breakaway devices. Brown and Henson (23, 61) provide recommended procedures for validating essential properties of surrogate vehicles.

Due to drop height limitations, pendulums are restricted to low-speed tests. However, since low- speed testing is critical for most heavy breakaway devices, pendulums have been widely used in the evaluation of the impact performance of breakaway luminaire poles. Bogie vehicles can be used for low- and high-speed tests of breakaway devices to evaluate their impact performance. For these tests, change in vehicle velocity during the crash and the impulse applied to the impacting vehicle by the breakaway device are the primary measures of impact performance. Velocity change during a test

of a breakaway device has been shown to be correlated to the stiffness of the front of a test vehicle (117). The crushable nose system now used on most surrogate test vehicles was calibrated to replicate the stiffness of a 1981 Volkswagen Rabbit. This vehicle does not meet the requirements of Section 4.2.1, and therefore, a new crushable nose must be developed to comply with the guidelines contained herein. Note that, as indicated in References 39 and 84, any new surrogate vehicles should be devel- oped to replicate a specifi c production vehicle, not a generic vehicle.

Pendulums and most bogie vehicles do not have the capability to assess the effects of test article impact with the windshield, roof, or undercarriage of a vehicle. However, these vehicles can be used to identify the potential for such contact to occur. If contact is indicated, the test should be repeated with a production vehicle. However, if no opportunity for contact is observed during surrogate vehicle testing, it is reasonable to assume that no contact would occur during a full-scale crash test with a pro- duction car. Note that bogie vehicles are beginning to be manufactured with a hood and windshield from a production vehicle. These new bogie vehicles can be used to evaluate the effects of test article

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contact with the hood and windshield area. However, these updated bogie vehicles still cannot be used to evaluate roof crush associated with heavy breakaway devices falling on top of the vehicle or contact with the undercarriage of a test vehicle.

* + 1. TRUCK-MOUNTED AND TRAILER-MOUNTED ATTENUATOR (TMA) SUPPORT VEHICLE

The impact performance of truck- and trailer-mounted attenuators can be strongly affected by the mass of the support vehicle. Light support trucks roll forward when a vehicle strikes the attenuator. This roll ahead effectively lengthens the attenuator and thereby increases its capacity to accommodate high- speed impacts. On the other hand, occupant risk factors for occupants of the support vehicle increase with lower weight. To assure that the occupant risk factors for the support truck driver are no more than those of the test vehicle occupants, the weight of the support truck should not be less than that of the test vehicle, i.e., 5,000 lb (2,270 kg).

Heavier support trucks reduce the roll-ahead effect and represent a more critical condition for TMA de- sign. However, designing TMAs for heavier support vehicles increases the required length of the TMA and thereby increases its cost. Developers must therefore determine the maximum weight of the support truck that can be used with each TMA design. All TMA testing must then be conducted with the maxi- mum allowable support vehicle weight. A TMA designed for an unlimited support truck weight should be tested with the support truck blocked against any roll ahead.

Although any vehicle can be used to support a TMA, in practice, dump trucks are used most often. Therefore, it is recommended that, unless the attenuator is designed for attachment to a very light sup- port truck, TMA testing should be conducted with an appropriately sized dump truck. The support truck should be placed in second gear with the parking brake engaged. Any necessary ballast should be placed in a manner to preclude movement during a high-speed impact with the rear of the vehicle. Ballast should either be securely anchored to the bed of the support truck or be placed at the back of the bed to minimize shifting during the test.

Documentation of support trucks should include year, make, and model of the truck as well as ballast mass, test inertial mass, and the horizontal c. g. location of the ballasted vehicle. The type, location, and manner of securing the ballast should also be reported. Finally, the condition and type of brakes used to reduce vehicle roll ahead should be documented.

### VEHICLE INSTRUMENTATION

Vehicle instrumentation is necessary to accurately measure vehicle accelerations and rotations during and after impact with a roadside safety feature. Tri-axial accelerometers are used to measure vehicle accelerations and a single-rate gyro is used to measure vehicle rotational rates. The following sections describe the specifi cations for electronic and photographic instrumentation of test vehicles.

* + 1. INSTRUMENTATION SPECIFICATIONS

Society of Automotive Engineers specifi cations for electronic and optical instrumentation (SAE J211-1 JUL2007 and J211-2 NOV2008) should be used as the primary reference instrumentation specifi cations.

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These specifi cations are reproduced in Appendix C. Part 1 relates to electronic instrumentation and Part 2 relates to photographic instrumentation. Part 1 of the specifi cations applies to the collection and analysis of vehicle acceleration and rotation data; determination of impact speed; and measure- ment, recording, and reduction of surrogate occupant data, including specifi cations for data channel performance requirements, data channel selection, transducer mounting, sign convention, digital data processing, timing marks, time of contact, and presentation of results. Part 2 of the standard addresses the use of photographic instrumentation to collect and analyze the same data.

Table 1 of J211 Part 1 presents a list of recommended Channel Frequency Classes (CFCs) for vari- ous application. Note that determination of vehicle velocity changes and occupant displacements are

critical to the impact performance evaluation process. As shown in Table 1, a CFC of 180 Hz is recom- mended for integration for velocity or displacement. Hence, accelerometers placed in a vehicle should, at a minimum, adhere to CFC Class 180 requirements and the data should be fi ltered at this level prior to processing. It should be further noted that, in Section 8.1, the standard recommends a pre-sample

fi lter corresponding to CFC 1000. Further, under Section 8.2, the standard indicates that the sampling rate should be no less than 10 times the pre-sampling fi lter frequency, or at least 10,000 Hz.

It is important to note that SAE J211-1 JUL2007 and J211-2 NOV2008 do not specify maximum transducer amplitude, called the Channel Amplitude Class (CAC). Instead, the standard leaves the selection of the CAC to the testing agency. Maximum transducer accuracy is achieved when record- ing near the mid-range of its amplitude. However, peak accelerations are often measured to be many times the average values during the primary impact sequence. Subjecting an accelerometer to ac- celerations higher than the CAC can potentially damage the unit and often cause any accelerometer data collected thereafter to be corrupted. The CAC should be selected to provide maximum accuracy without exposing the transducer to undue risk of damage. Users should examine the results of similar tests when selecting a CAC to meet this goal.

Although SAE J211-1 JUL2007 and J211-2 NOV2008 do not specify specifi c coordinate axes, it does recommend that a right-handed coordinate system be used. However, in order to maintain consistency with NCHRP Report 350 guidelines, the following right-handed sign convention is recommended:

*x*—Positive in the normal forward motion direction

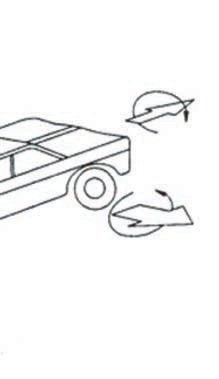
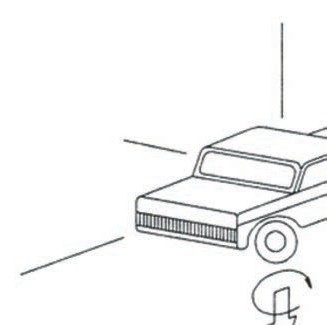
*y*—Positive toward the right

*z*—Positive downward

These sign conventions should be followed whenever acceleration, velocity, or displacement data must be presented. Note that some testing agencies tend to reverse acceleration signs in order to produce a plot that is primarily in the fi rst quadrant. Although these changes are relatively simple to implement, the revisions can lead to confusion. Therefore, it is recommended that the sign convention shown above and in Figure 4-6 be utilized whenever any acceleration, velocity, or displacement data is presented. Note that, as shown in Figure 4-6, the origin of the coordinate system is placed at the vehicle center of gravity. Further, it is recommended that vehicle accelerations be fi ltered at 60 Hz for the purposes of presentation of accelerometer data in reports.

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+Y, +Pitch



+X, +Roll

Figure 4-6. Recommended Vehicle Coordinate System

+Z, +Yaw

SAE J211-1 JUL2007 also includes recommendations for the collection of vehicle crush data. For purposes of impact performance evaluation, it is recommended that vehicle crush data be collected and reported in accordance with Section 4.2.1.4 of this chapter and guidelines shown in Appendix E.

Other exceptions to the application of SAE J211-1 JUL2007 and J211-2 NOV2008 include:

* + - Section A.2.2 of Part 1 is optional.
    - Section A.3 of Part 1 is not applicable.
    - Overall error as defi ned in Section 4.1.1 of Part 2 should generally be less than one percent, unless

using a wide-angle lens. The overall error associated with the each camera and lens combination used in the test should be reported along with the results of any fi lm analysis.

* + 1. ACCELEROMETER AND RATE GYRO PLACEMENT AND DATA REDUCTION

Occupant risk parameters are to be measured with respect to accelerations measured near the vehicle center of gravity. Therefore, it is important that a tri-axial set of accelerometers be placed at or near the center of mass. If a tri-axial accelerometer cannot be placed within 2 in. (50 mm) of the center of mass as measured in the horizontal plane, it is recommended that the instrumentation and data reduction method given in Appendix A, Section A4.3.2 be used. Even though occupant risk measures are not cal- culated for heavy truck tests, it is recommended that tri-axial accelerometers be mounted near the center of gravity for these vehicles as well. If possible, two pairs of tri-axial accelerometers should be used

for each truck. One pair of accelerometers should be mounted on the tractor portion of combination vehicles, and the other pair should be mounted on the trailer portion. Note that the 10000S single-unit truck can behave as an articulated vehicle with a hinge between the cab and the truck box. Therefore, it should be treated the same as a combination vehicle with a pair of tri-axial accelerometers forward of the truck box attachment and another pair in the cargo area. Under this instrumentation plan, the analy- sis procedure from Section A4.3.2 of Appendix A can then be used to determine lateral accelerations at any point along the truck or trailer/cargo area.

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Most vehicle components vibrate during a high-speed crash test. Because structural vibrations do not contribute to overall vehicle motion, it is desirable to avoid mounting accelerometers in a location where these vibrations will contribute signifi cantly to the recorded data. Therefore, it is recommended that accelerometers be mounted directly to a structural element of the vehicle in order to assure a high stiffness of the mounting point. Most agencies mount transducers on the vehicle fl oor board. Care should be taken to avoid mounting transducers to portions of the fl oor board that could be expected to deform during the crash. It is inappropriate to mount transducers to a frame that offsets accelerometers from the structural components of the vehicle. The inherent fl exibility of such a frame creates a struc- tural fi lter that produces an unknown phase shift and spreading of the acceleration trace. Further, it is desirable to combine accelerometers on a common structure, such as a metal block. However, the mass of the metal block should be minimized in order to reduce the effects of the added mass on the vibration of the structural element to which it is attached.

For all test vehicles, a rate gyro should also be mounted as near to the center of gravity as possible. Like accelerometers, the rate gyro should be attached to a stiff structural element to prevent local rotations of the vehicle structure from distorting the gyro data. It is recommended that two rate gyros be mounted on heavy truck test vehicles, one on the cab or tractor and another in the cargo area or on the trailer. Rate gyro data is collected about the local vehicle axes and therefore the measured roll, pitch, and yaw rates are coupled. This data must be decoupled using one of the commonly available procedures, such as the Test Risk Assessment Program (TRAP) Program (143). Note that the rate gyro transducers should be selected to preclude the possibility of test rotational rates from exceeding the maximum range. Note that rotational rates during full-scale crash tests can sometimes exceed 1200 degrees per second.